Multi-decade longitudinal analysis of urban expansion and the growth of transport networks in the Greater Toronto-Hamilton Area (GTHA) and the impacts of changing transport accessibility levels on travel behaviour in the region

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
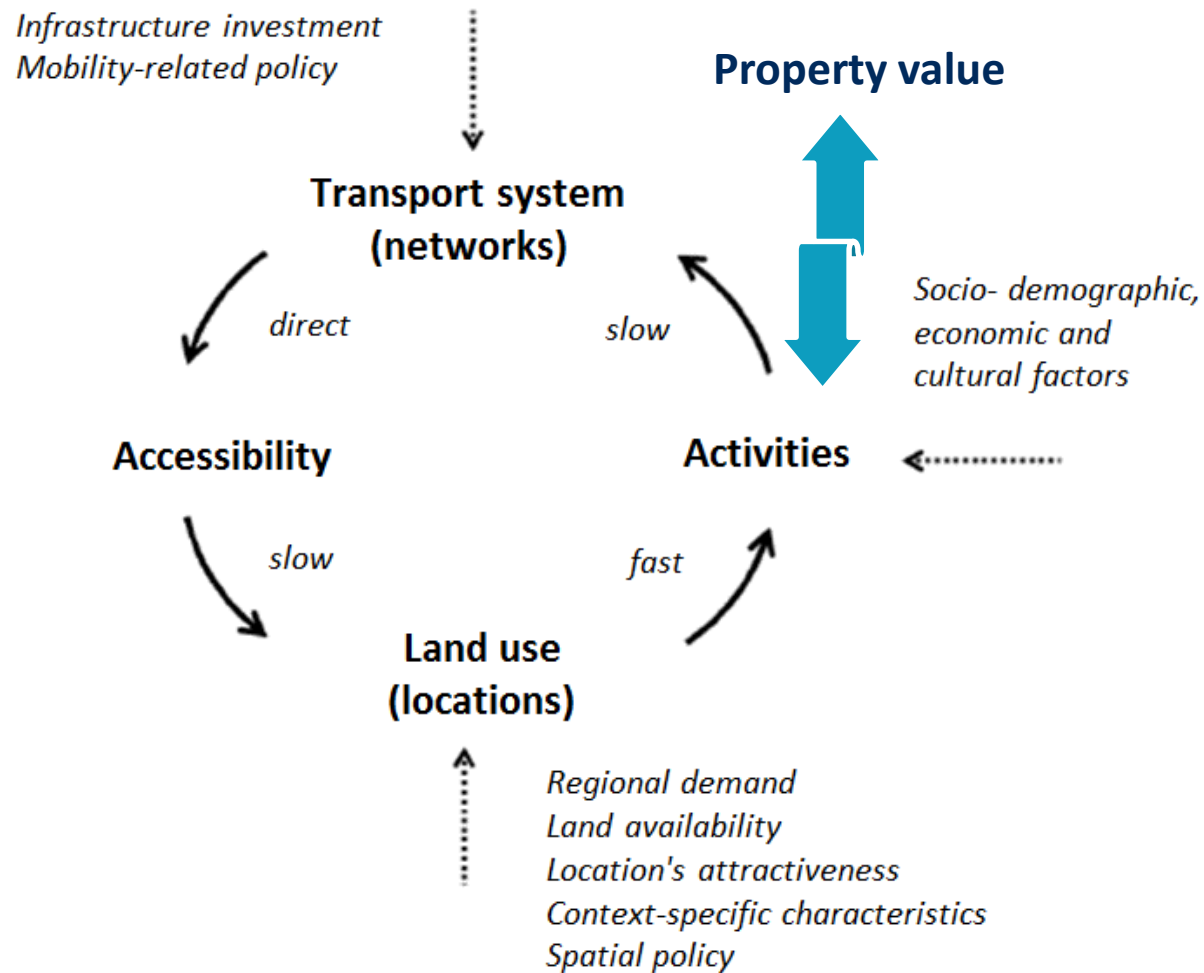Transportation Research Institute

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Outline

- Background

- Data collection and manipulation

- Spatio-temporal distribution of urban attributes

- Preliminary analyses and findings

- Model results

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The transport-land use feedback cycle

Source: Wegener & Fürst, 1999; adapted by Bertolini, 2012

Research goals

- Development of a comprehensive urban database of the GTHA from 1971-2016
  - collection and manipulation of time-series socio-economic variables, built environment and transportation measures
  - merge datasets and organize as a relational database

- Longitudinal analysis of:
  - the role of road and transit accessibility in urbanization
  - travel behaviour in terms of vehicular/passenger kilometers travelled (VKT/PKT) to identify the determinants of travel demand
  - the factors influencing housing prices (underway)

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Greater Toronto-Hamilton Area (GTHA)

Built up area and transportation networks (2016)

Legend
- ○ GO stations
- —— GO lines
- —— Highways
- ■ Built-up Area

0 5 10   20   30 Kilometers
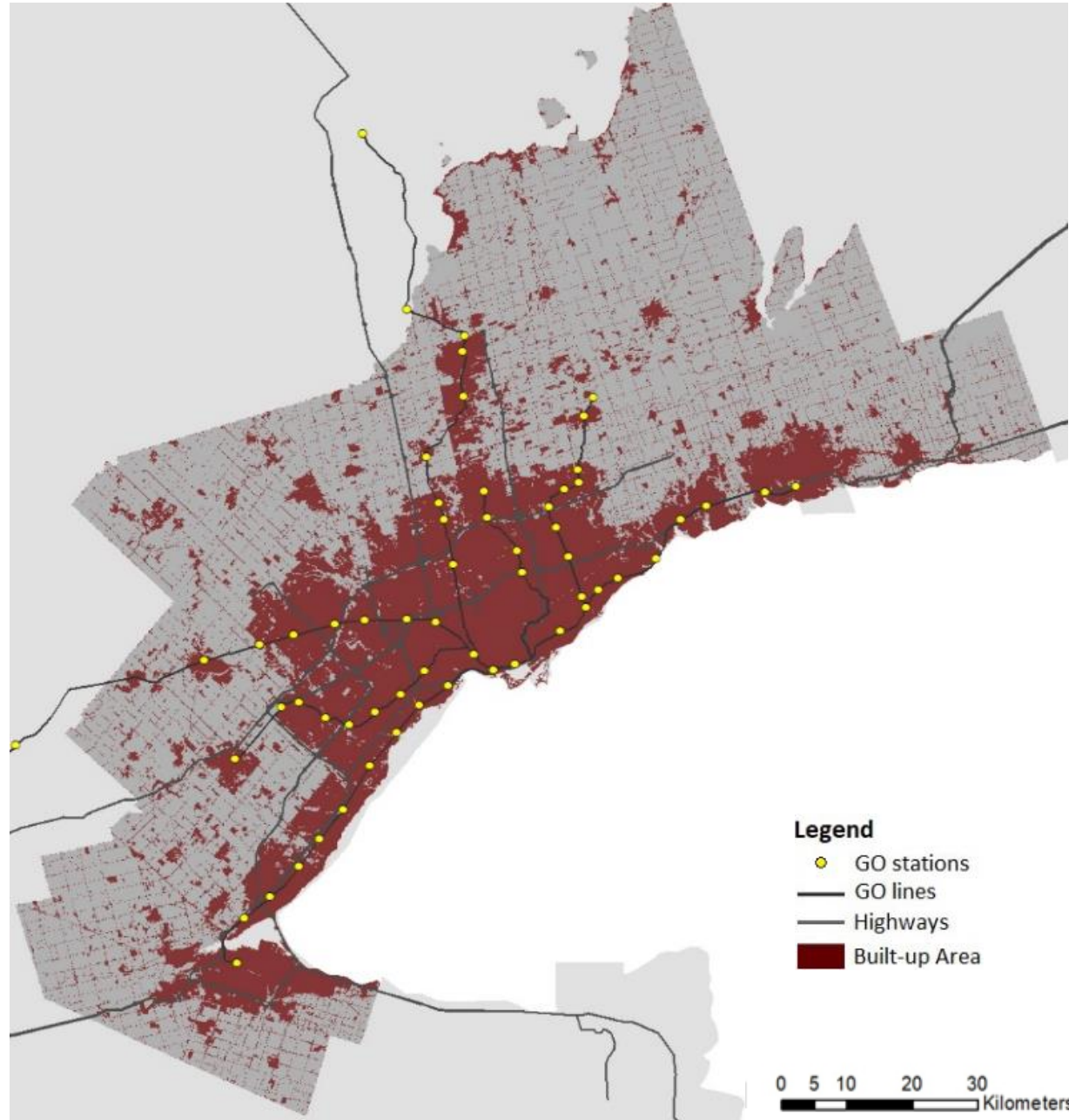
Data collection and manipulation

Land use-transportation-housing database

Socio-economic variables

- Census
- Transportation Tomorrow survey (TTS)

Built environment variables

- Land cover datasets from Natural Resources Canada
- Census
- DMTI Spatial; computed on GIS

Real estate sales transaction data

- Teranet

Transport accessibility and travel demand data

- EMME transportation networks (Travel Modelling Group, UTTRI)
- TTS

Other sources: Statistics Canada, CMHC, Municipal open data websites

Temporal limitations of data sources

| DATA SOURCES	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Census			■					■					■					■		
TTS			■					■					■					■		
DMTI land use			■	■	■	■	■	■	■	■	■	■	■	■	■					
DMTI EPOI			■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■
EMME network variables			■					■					■					■		
Teranet data	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Dept. of Geography land use													■	■	■					
Macro supply/demand variables	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Study time frames:
- 1971 to 2016 for urban growth study (5-year time points)
- 1986 to 2016 for travel behaviour study (5-year time points)
- 2001 to 2016 for housing market study (annual)

Differences in spatial units between data sources

Spatial unit	Data	Standard boundary
Point data	• Teranet sales records (X-Y coordinates of parcel centroid) • Points of Interest from DMTI	2016 Teranet parcels
Parcel-level data (polygons)	• Detailed land use from the Department of Geography	2016 Teranet parcels
DA-level data (polygons)	• Census variables • GIS built environment variables • Land use from DMTI	2016 DAs
TAZ-level data (polygons)	• TTS variables • EMME network variables	2001 zone system
Municipal and regional data (polygons)	Macro supply/demand variables • Census • CMHC • Bank of Canada • Statistics Canada	2016 CSDs 2016 CDs and CMAs

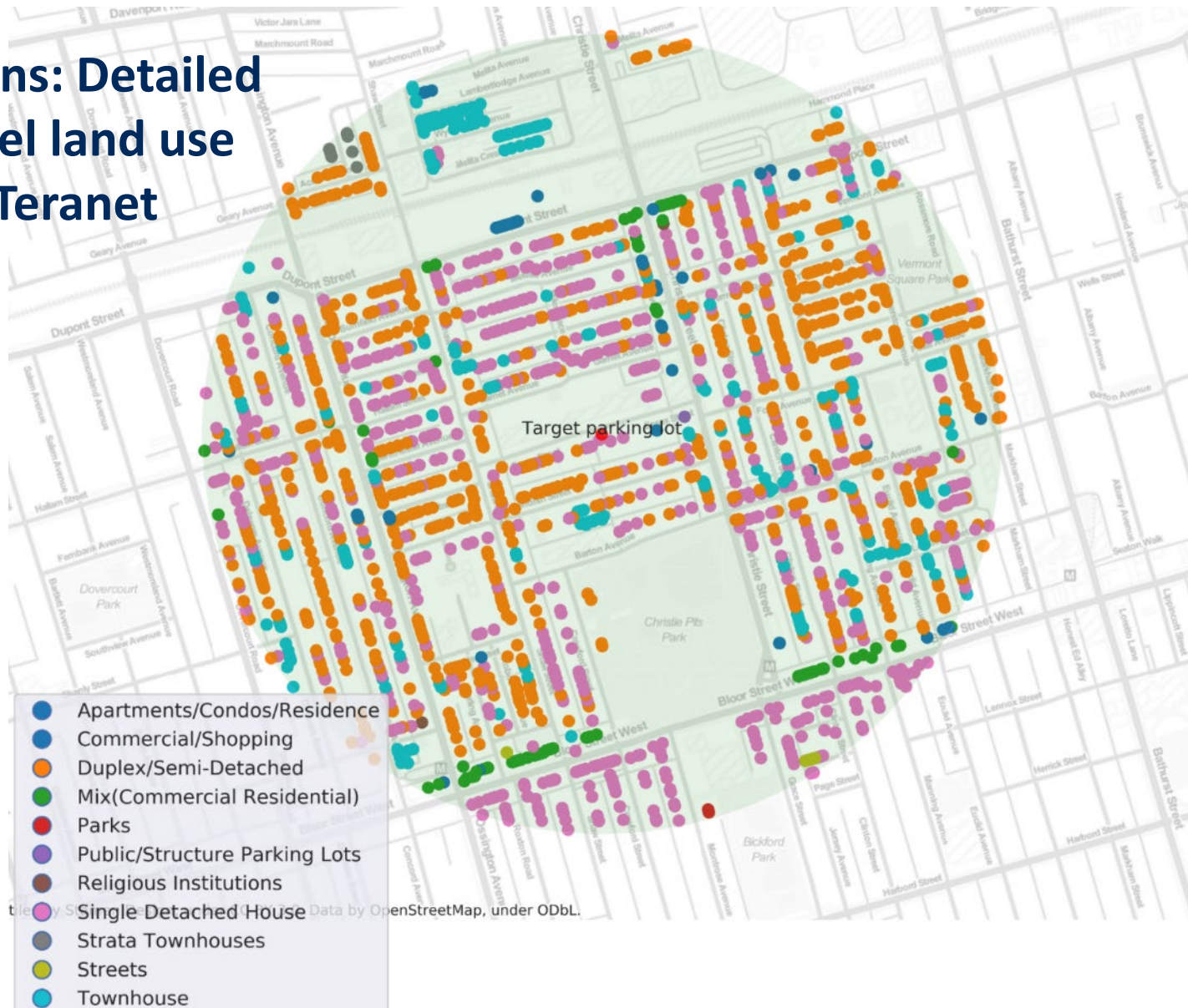# Area-weighted spatial interpolation for consistent boundaries

Difference between TAZ (red) and DA (black) boundaries
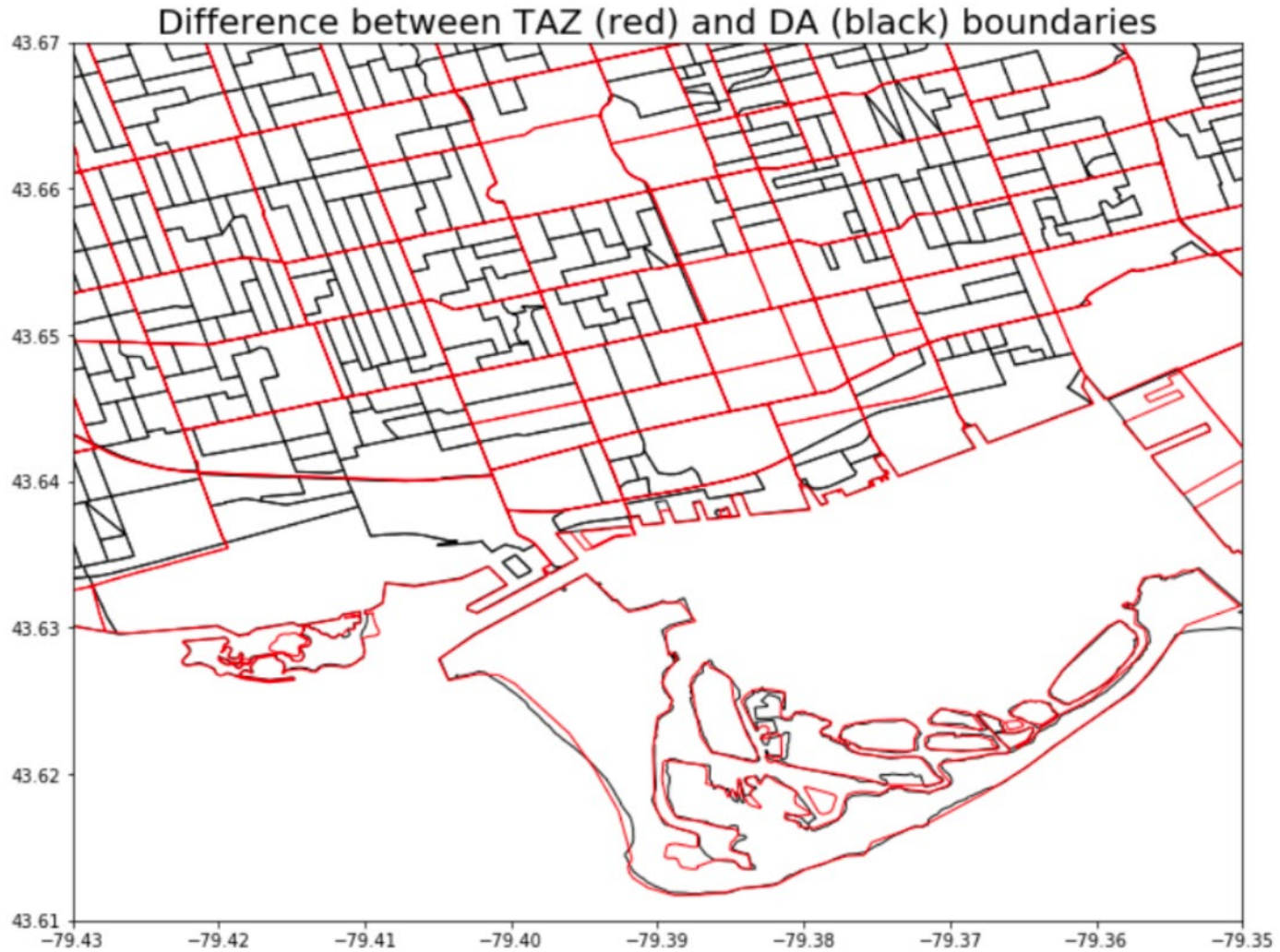
Neighbourhood amenities (POI)
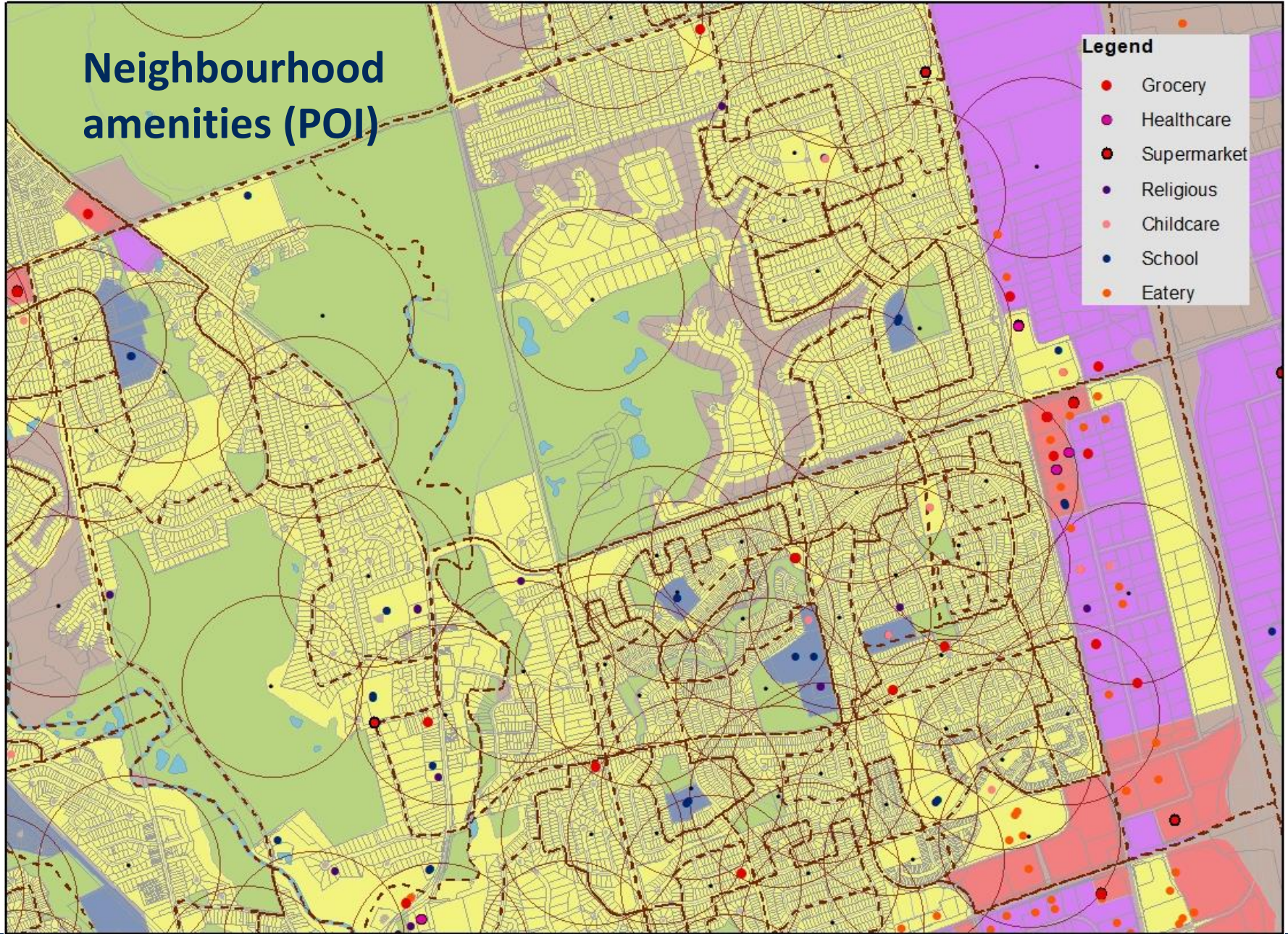
Legend
- Grocery
- Healthcare
- Supermarket
- Religious
- Childcare
- School
- Eatery

Spatial joins: Detailed parcel-level land use joined to Teranet records

Legend:
- Apartments/Condos/Residence
- Commercial/Shopping
- Duplex/Semi-Detached
- Mix(Commercial Residential)
- Parks
- Public/Structure Parking Lots
- Religious Institutions
- Single Detached House
- Strata Townhouses
- Streets
- Townhouse

Target parking lot

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Spatio-temporal distribution of urban attributes

Population density (Census)

2016

Population Density

- 0 - 500
- 501 - 1000
- 1010 - 2000
- 2010 - 5000
- >5000
- External zones

Job density (TTS)

2016

Jobs/Sq.Km.
- 0 - 50
- 51 - 500
- 501 - 2000
- 2001 - 10000
- 10001 - 360000
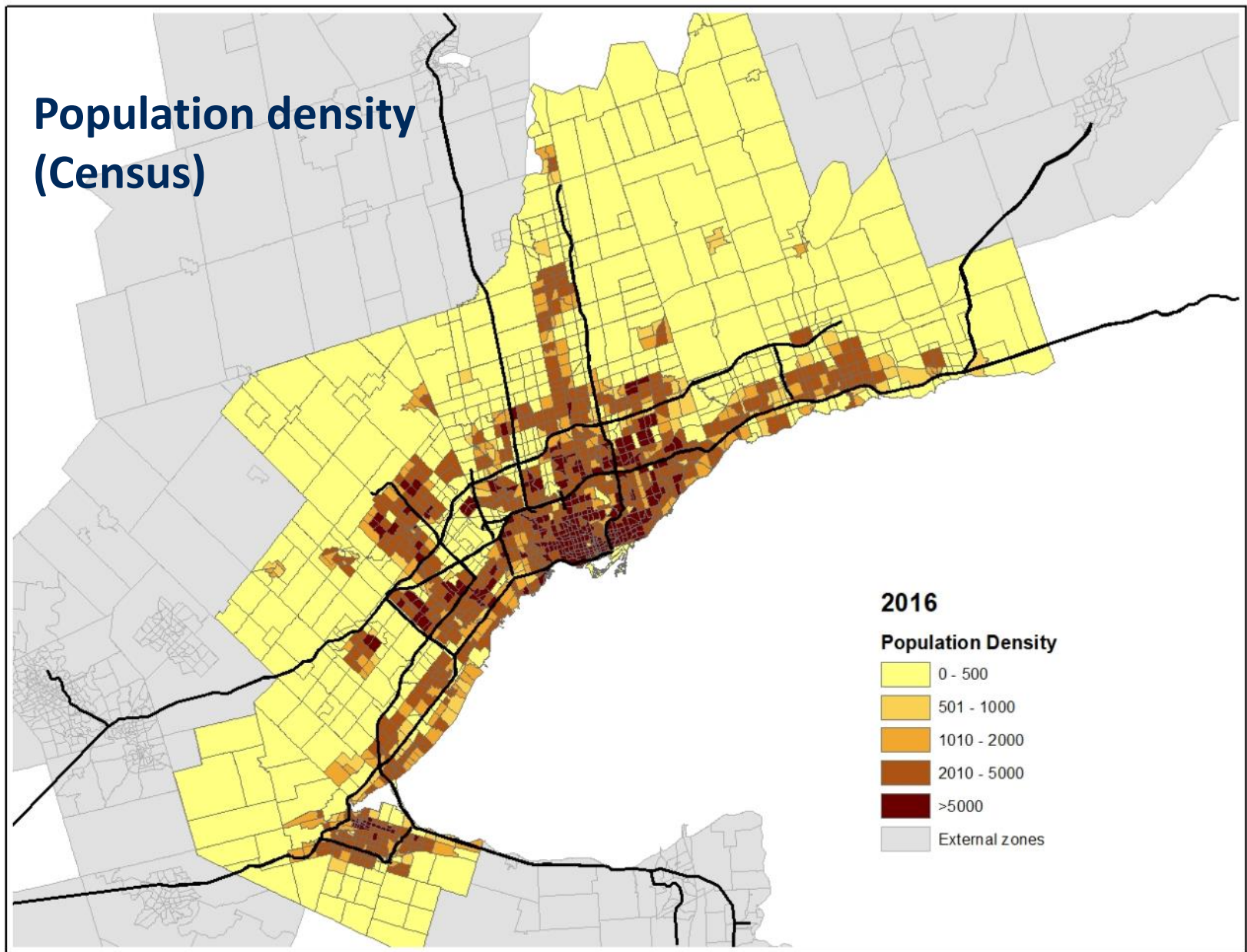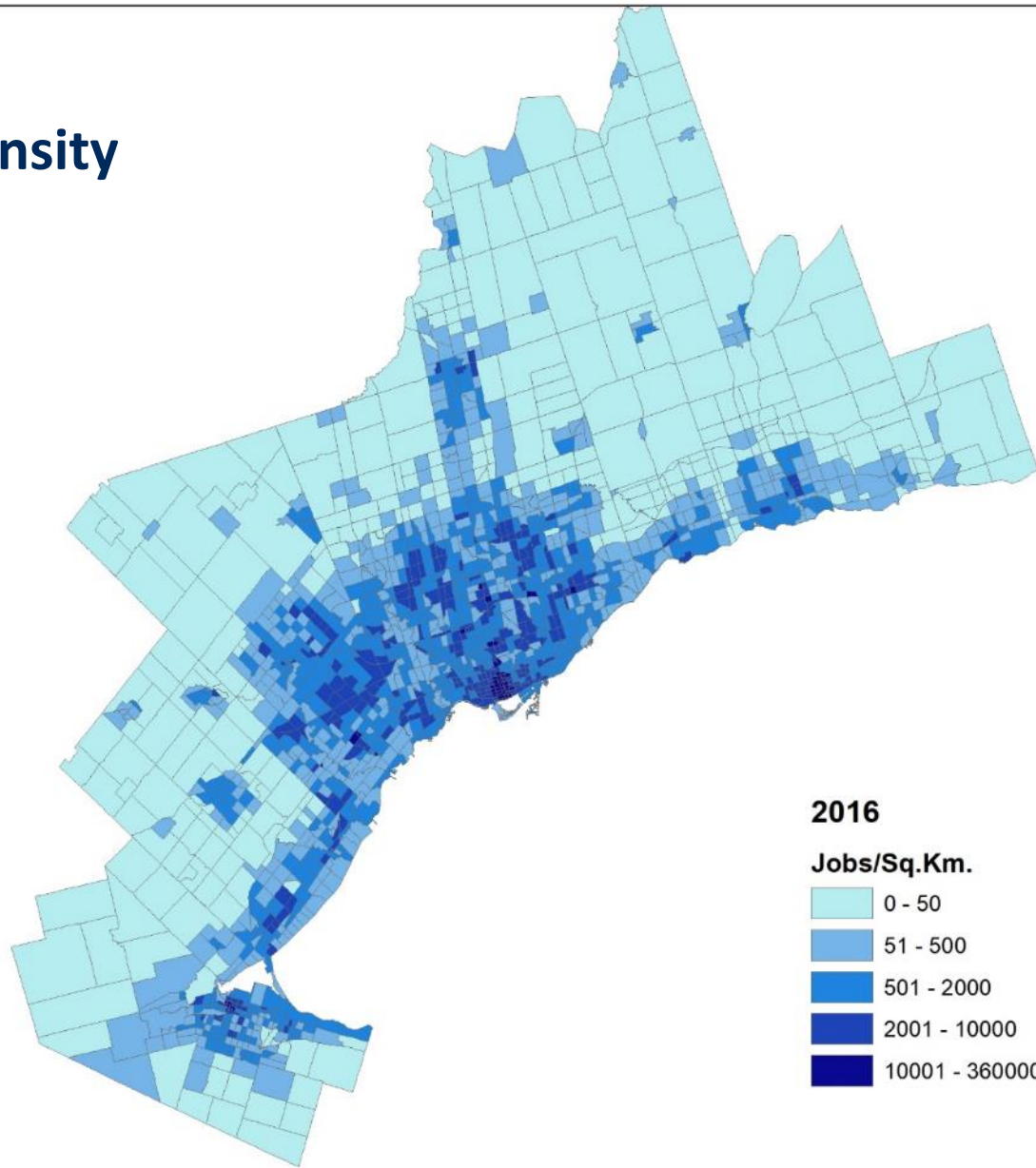
Average travel time (mins) by car (EMME Model)
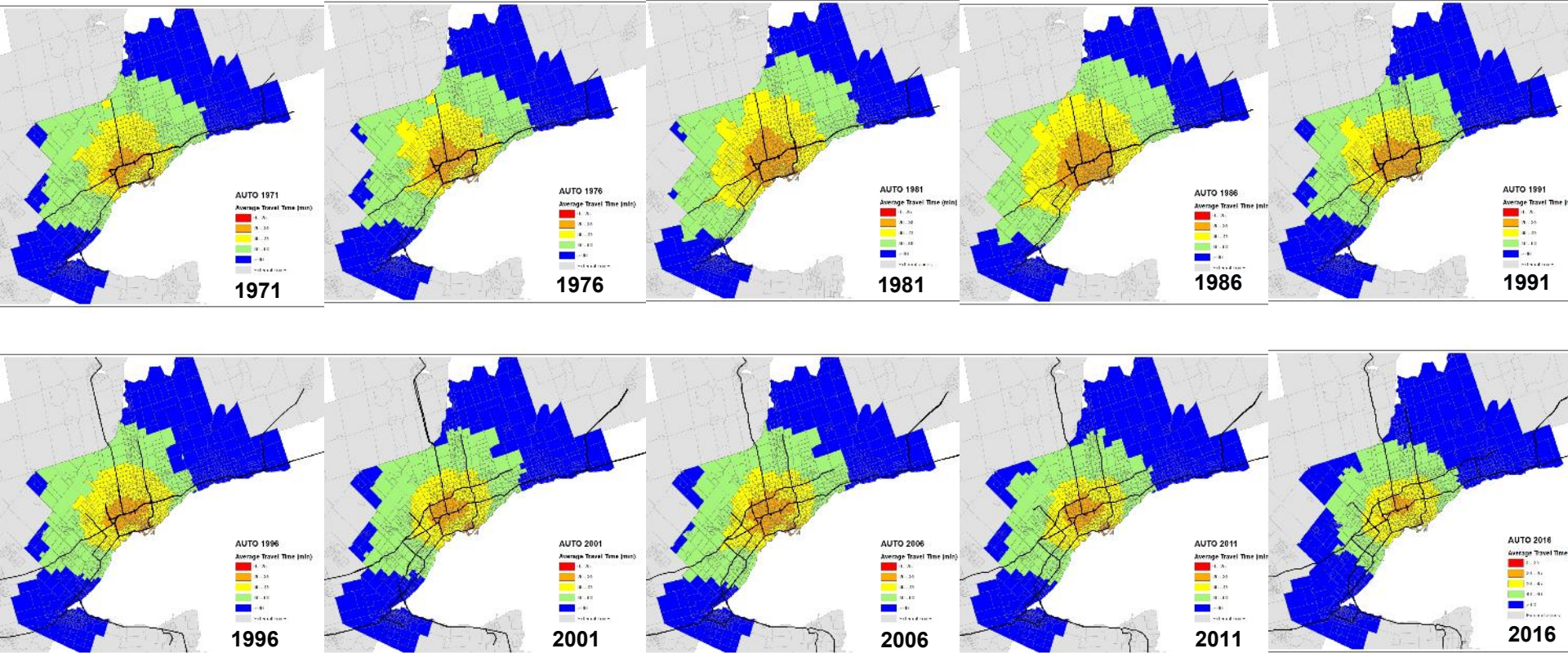
Average travel time (mins) by transit (EMME Model)
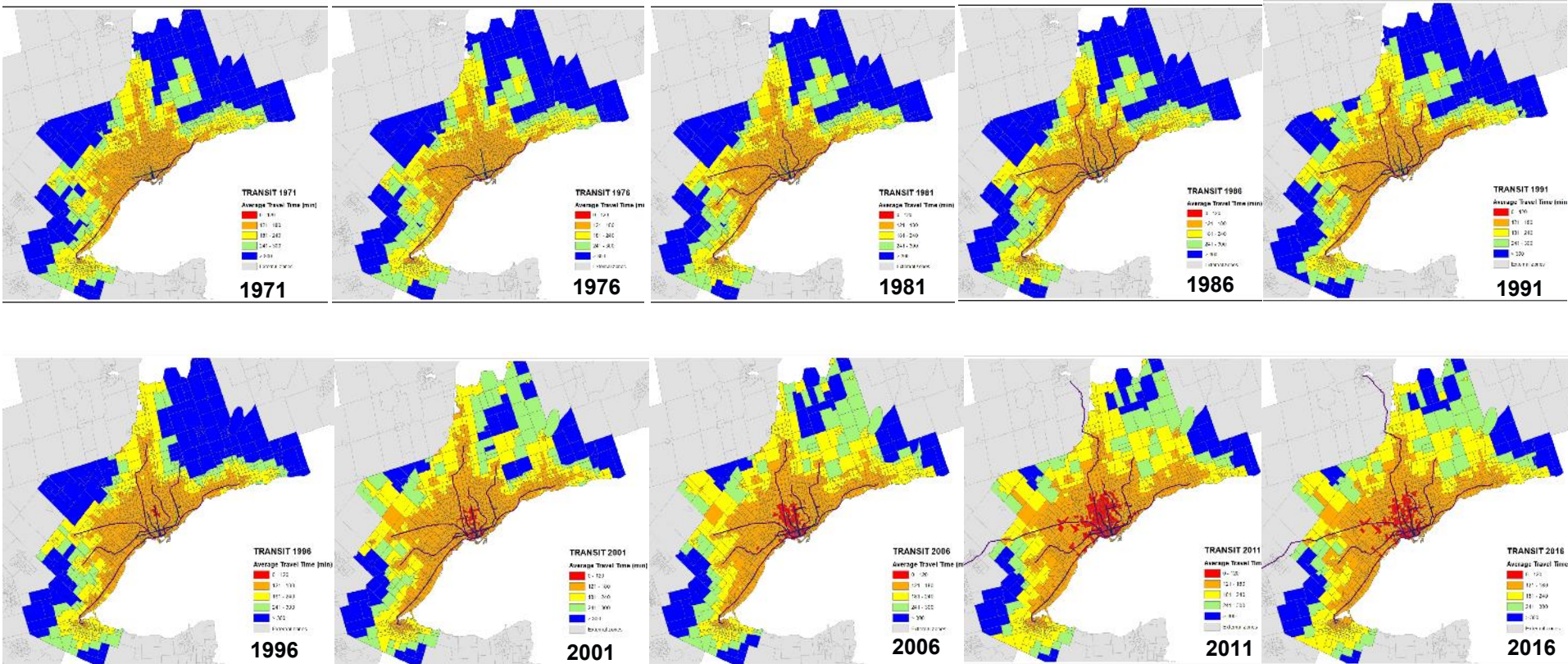
Potential accessibility to population and jobs (computed)
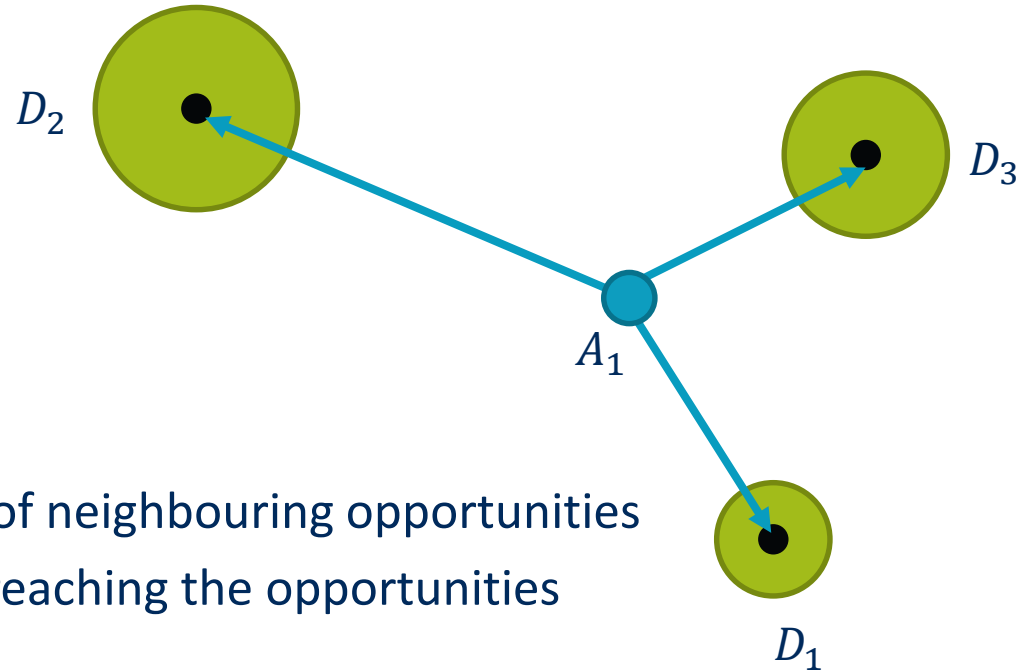
Potential accessibility:

- Increases with the amount of neighbouring opportunities
- Decreases with the cost of reaching the opportunities

$$A_i = \sum_{j=1}^{n} D_j e^{-\beta c_{ij}}$$

D_j = population of zone j

C_{ij} = travel time between i and j

Potential accessibility by car
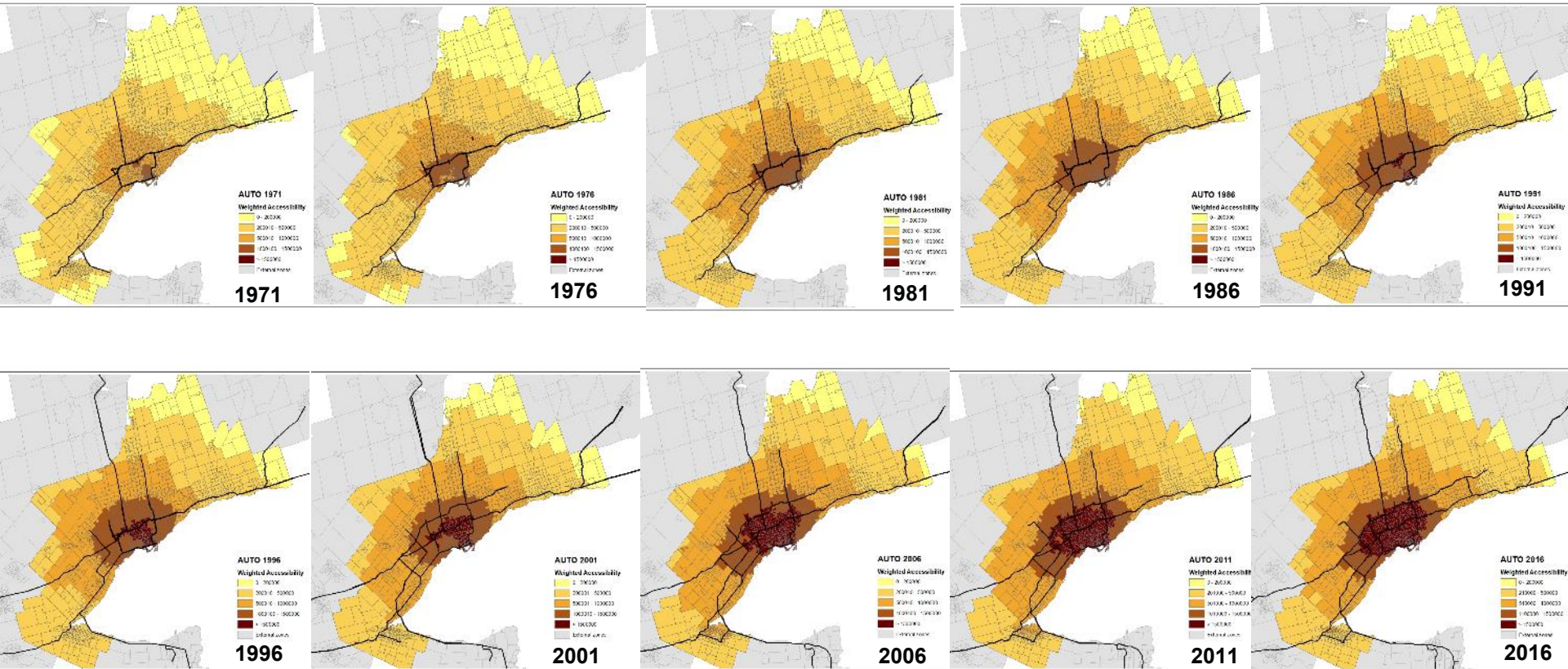
Potential accessibility by transit
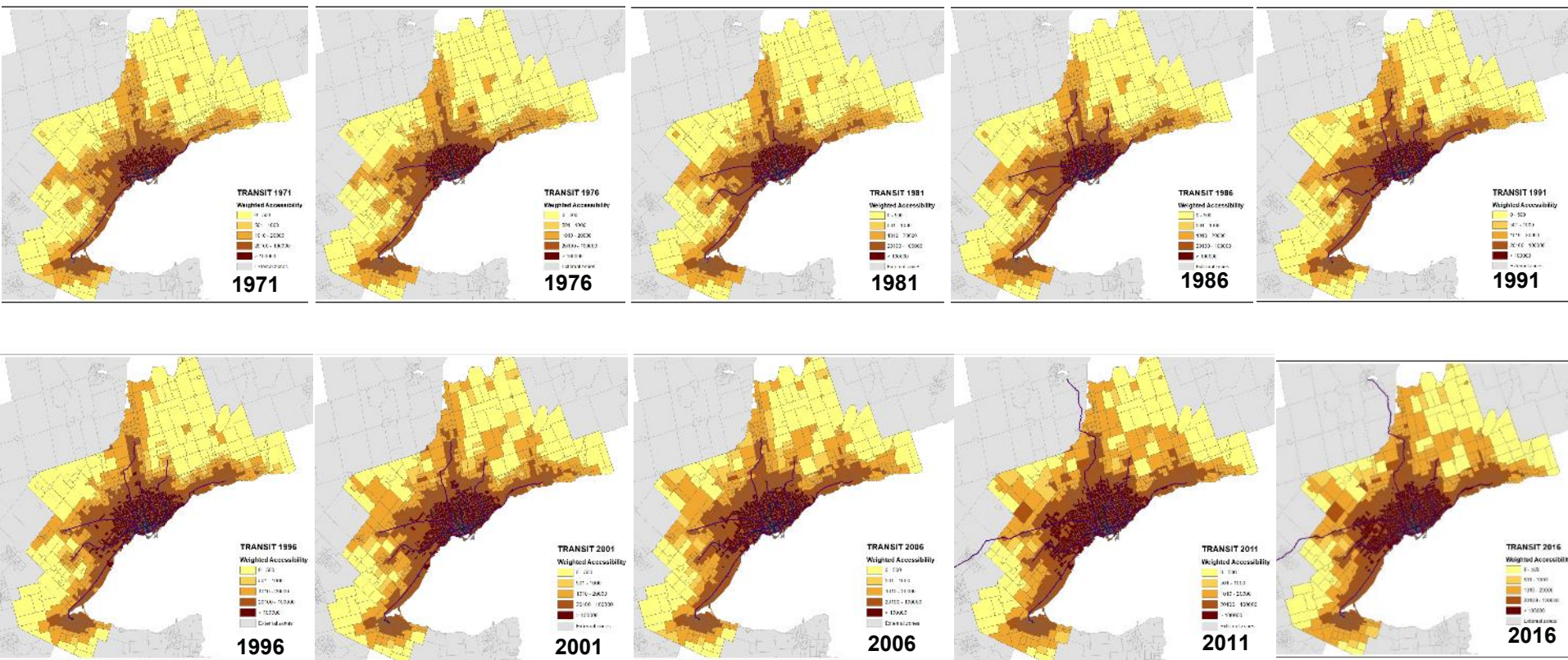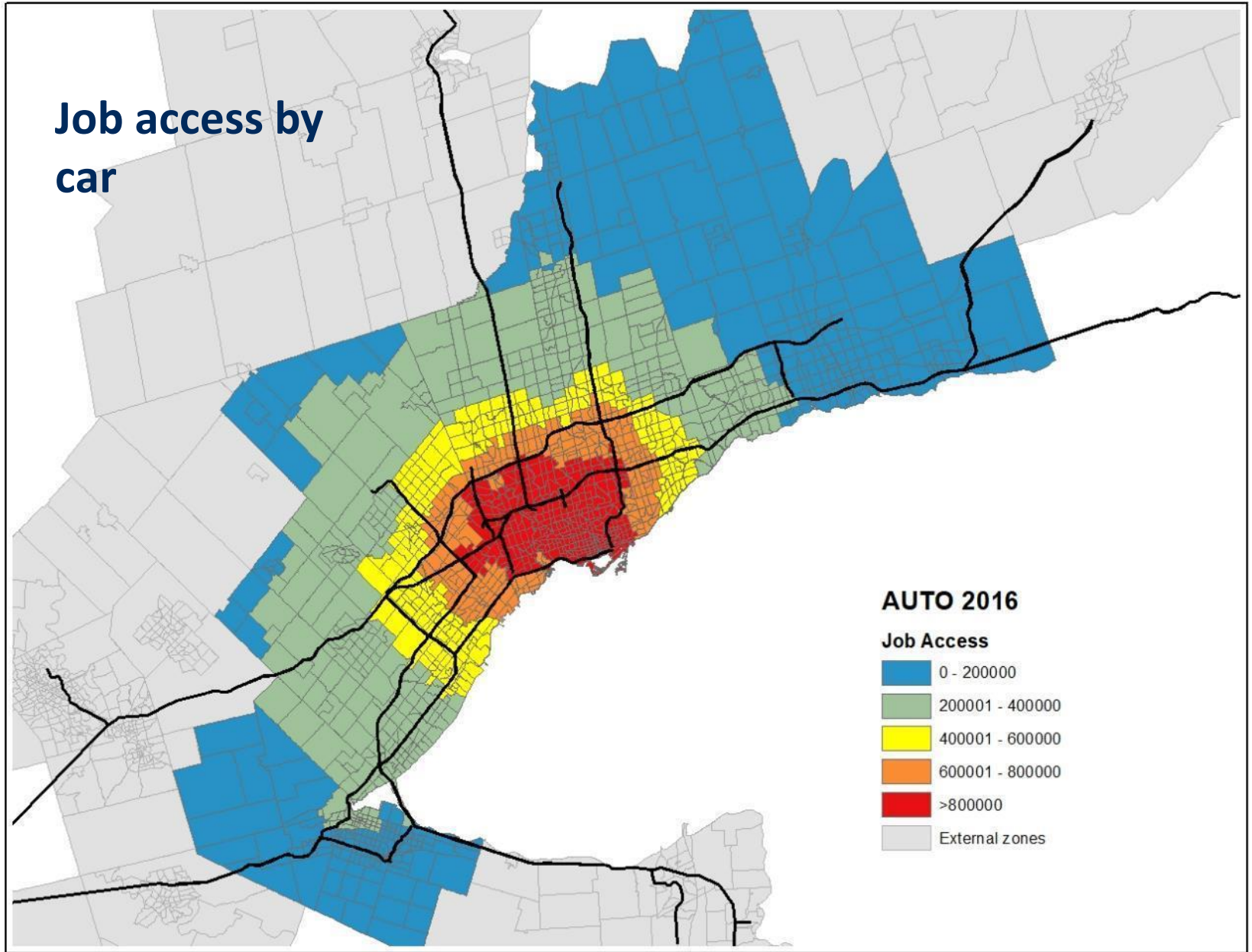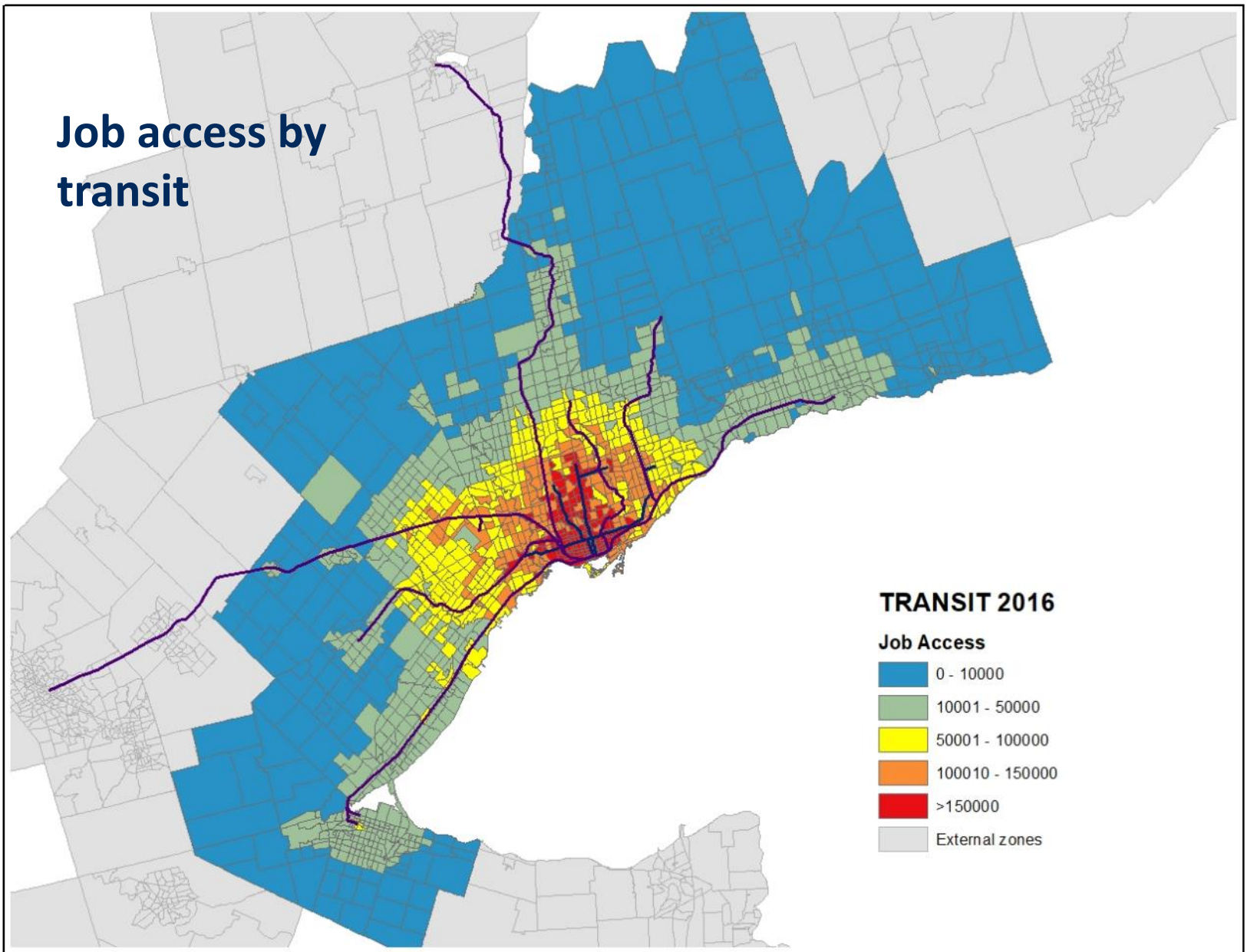
1971

1976

1981

1986

1991

1996

2001

2006

2011

2016

Job access by car

AUTO 2016

Job Access
- 0 - 200000
- 200001 - 400000
- 400001 - 600000
- 600001 - 800000
- >800000
- External zones

Job access by transit

TRANSIT 2016

Job Access
- 0 - 10000
- 10001 - 50000
- 50001 - 100000
- 100010 - 150000
- >150000
- External zones

Urbanisation and railways development in the GTHA

1971

Toronto

Hamilton

0 5 10 20 30 40
Kilometers

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Urbanisation and railways development in the GTHA

1981

Toronto

Hamilton

0 5 10 20 30 40 Kilometers

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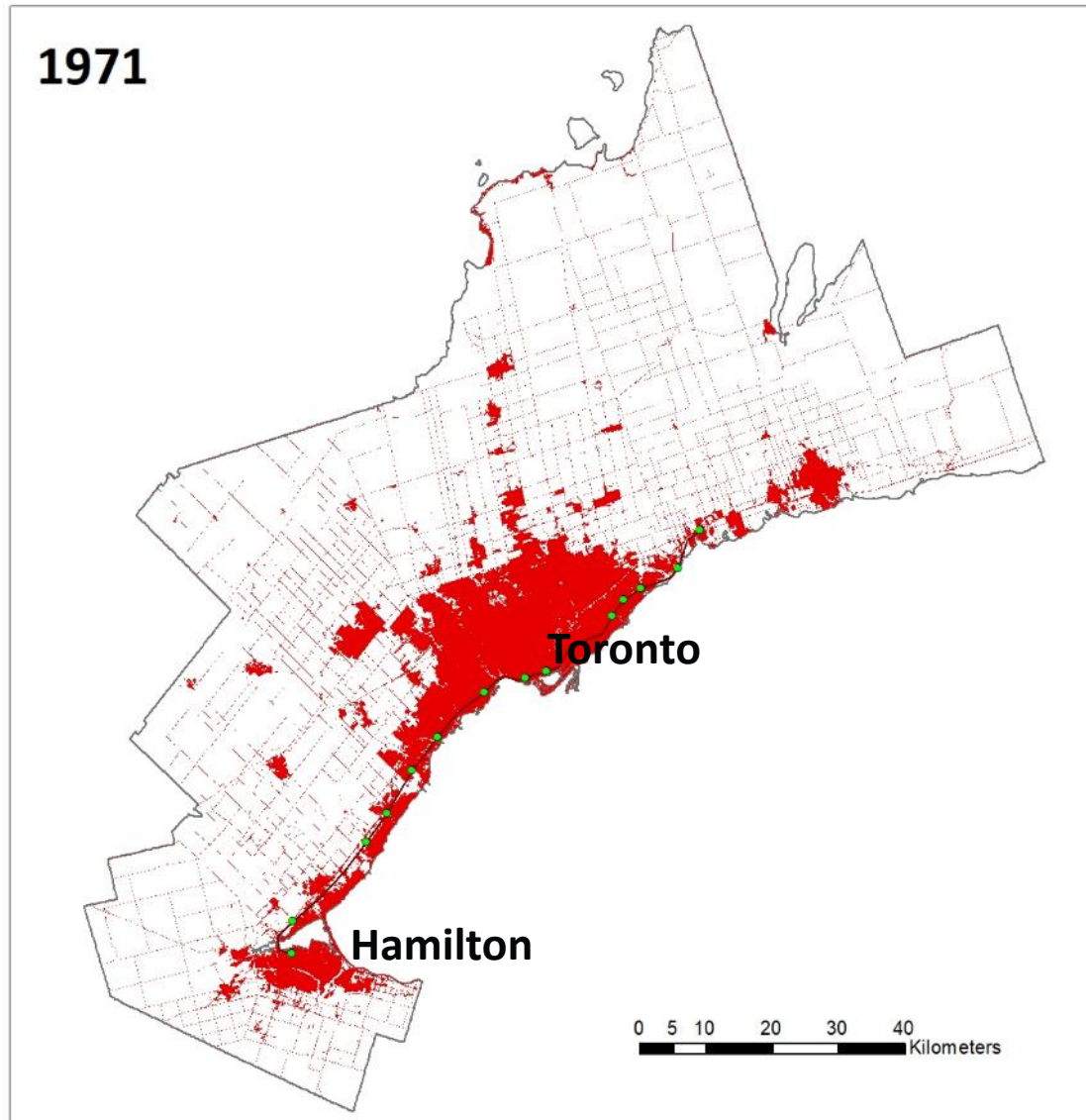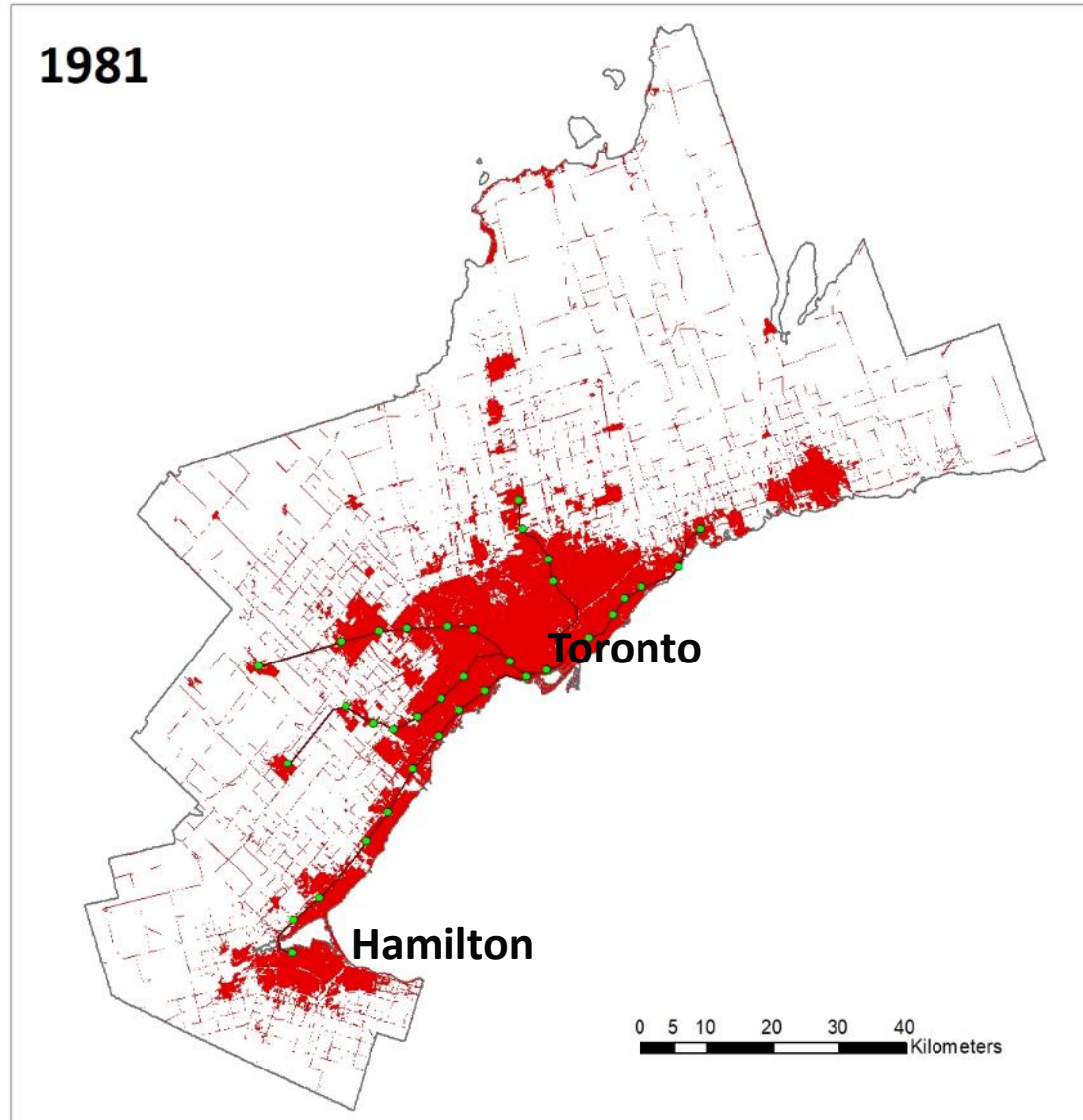
Urbanisation and railways development in the GTHA
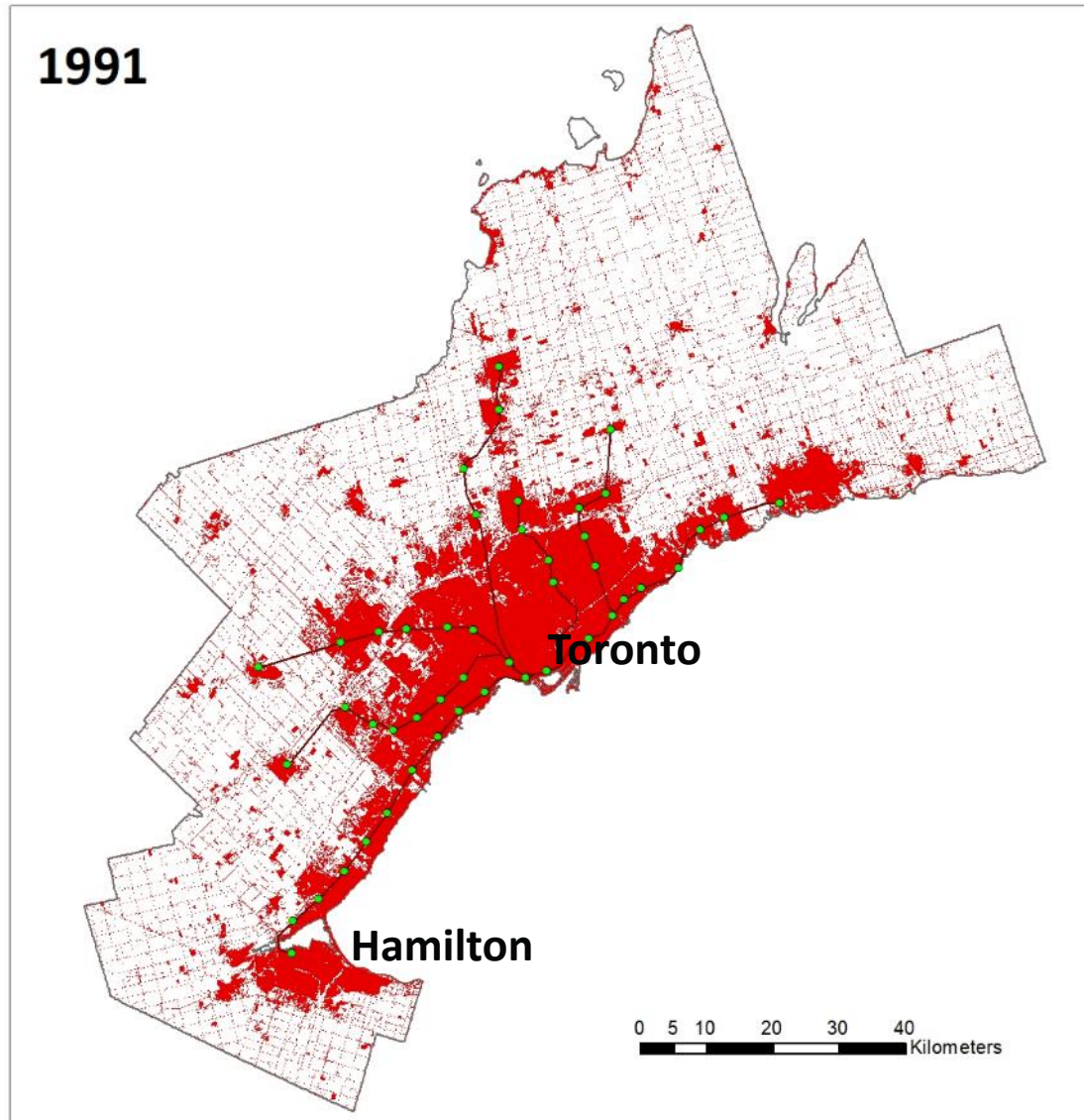
Urbanisation and railways development in the GTHA
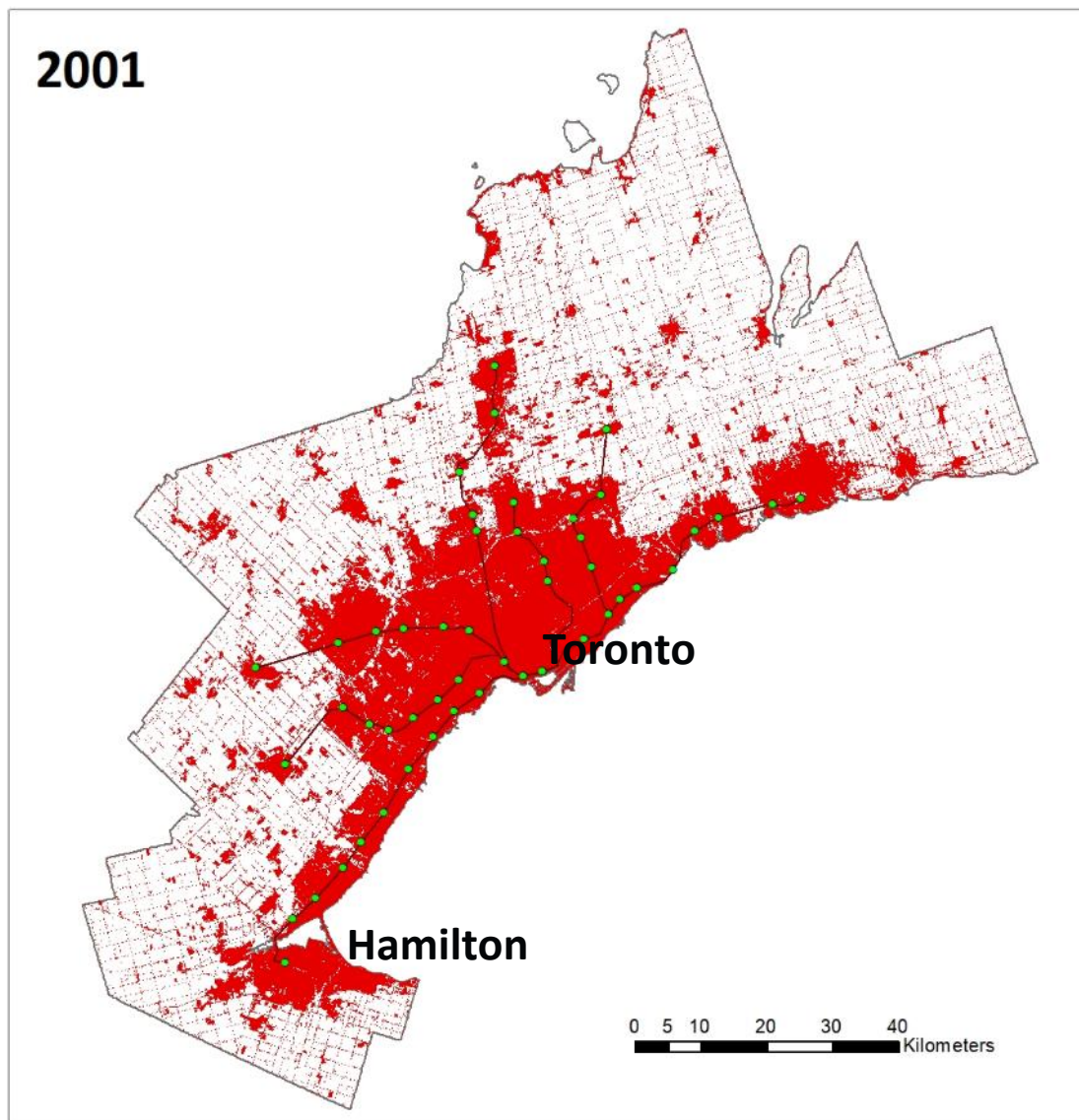
Urbanisation and railways development in the GTHA

➢ Built up area (BUA) growth of 130% across the GTHA over 45 years

2011

Toronto

Hamilton

0 5 10 20 30 40 Kilometers

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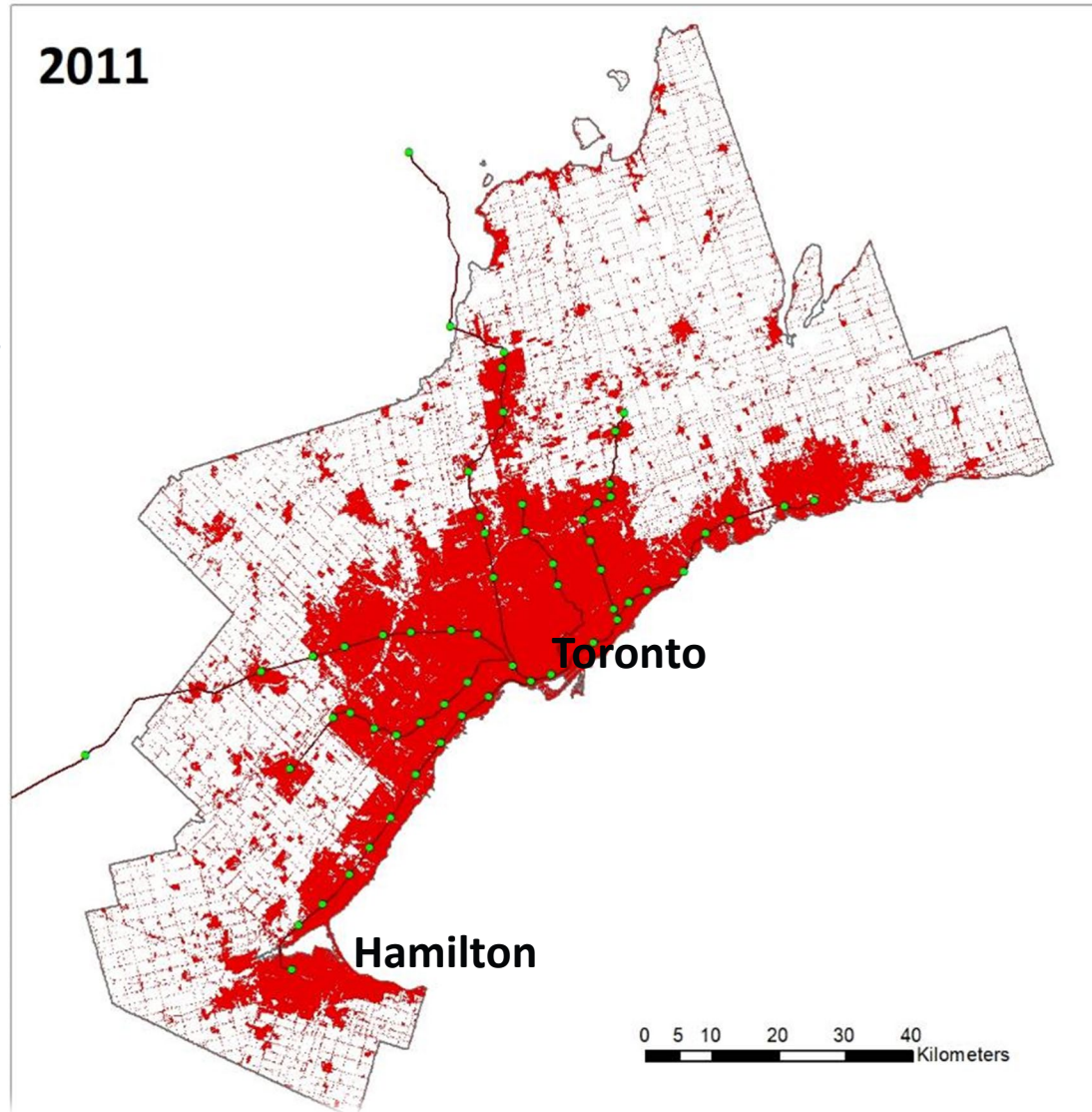
Preliminary analysis and findings:
Urban growth study

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Transit network length (km) & number of station openings

Transit network length [km] — Subway line, GO Transit line

Transit station openings — Subway stations, GO Transit stations
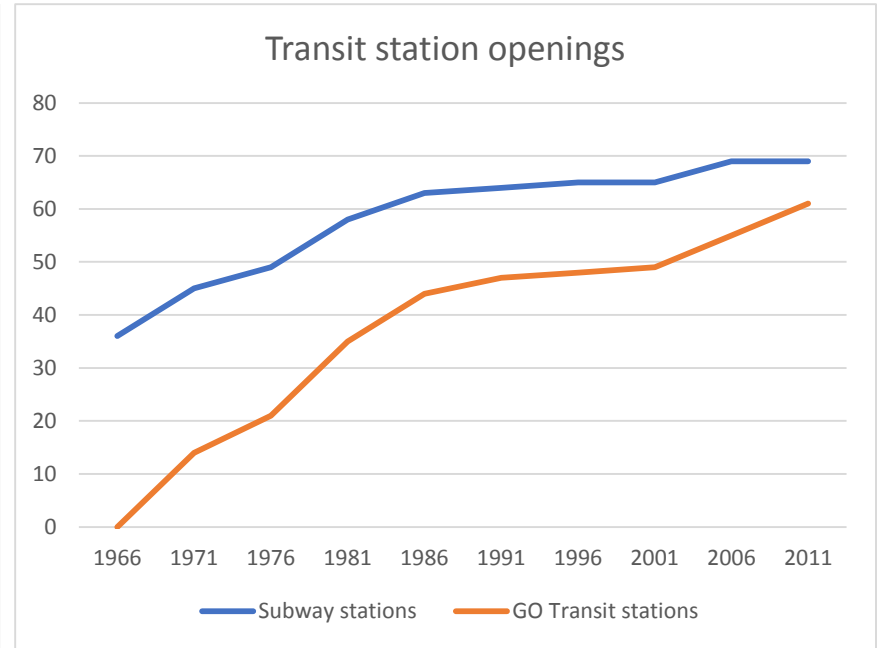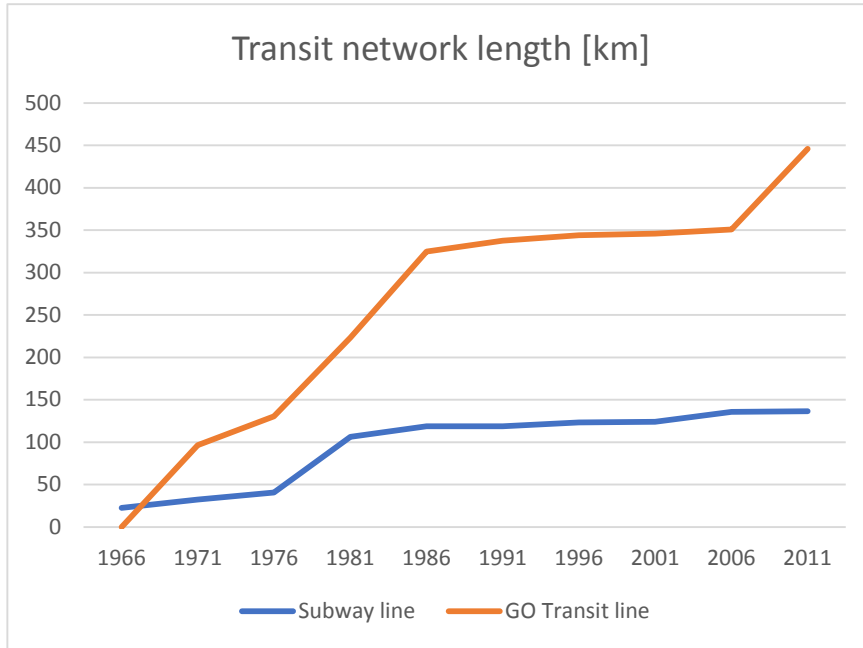
Population and transport infrastructure growth
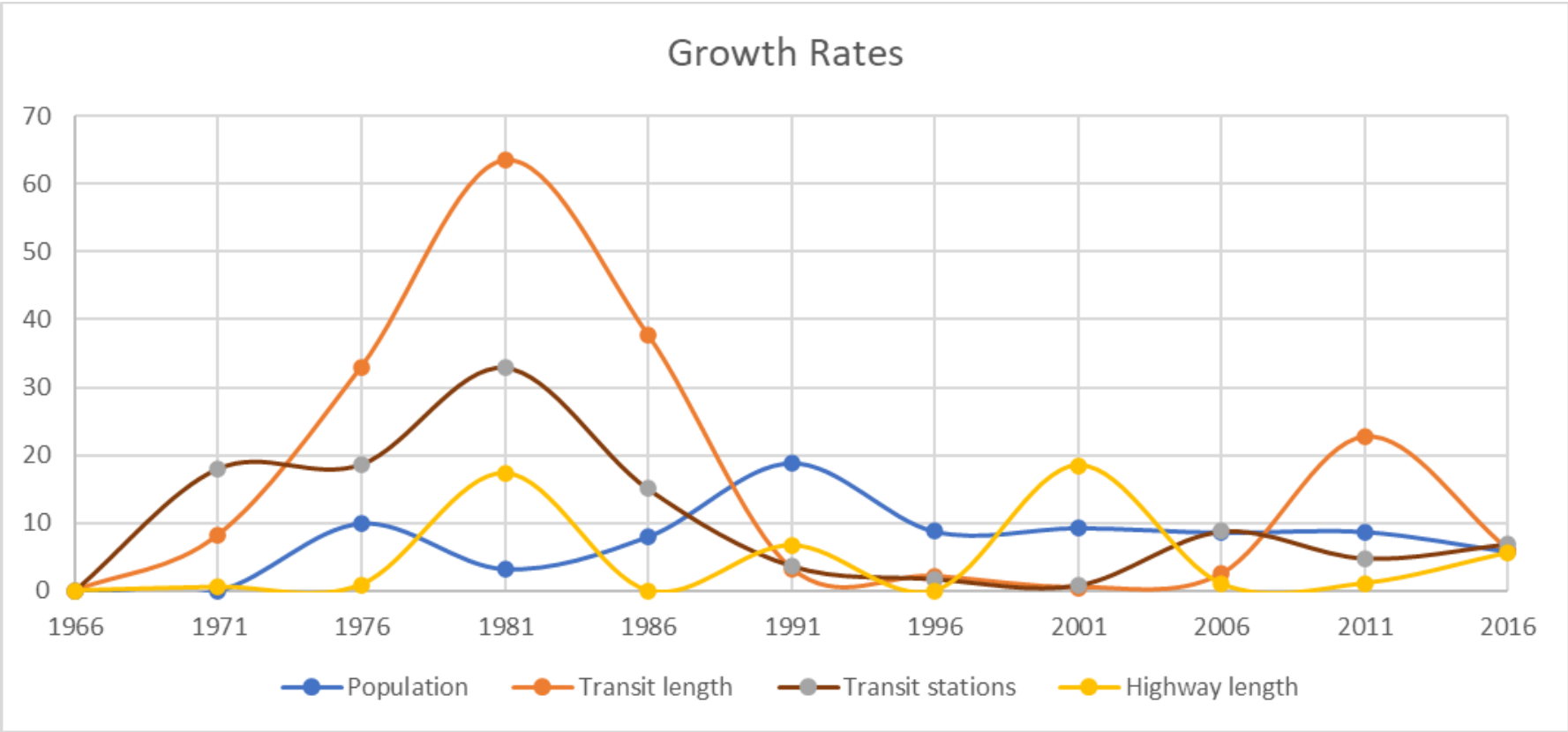
Measuring urbanization in 1-5 km buffers of stations and exits over time

Legend

- ● GO Stations 2011
- — GO lines 2011
- • Highway exits 2011

Intersected BUA

- 4-5km
- 3-4km
- 2-3km
- 1-2km
- 0-1km
- BUA 2011

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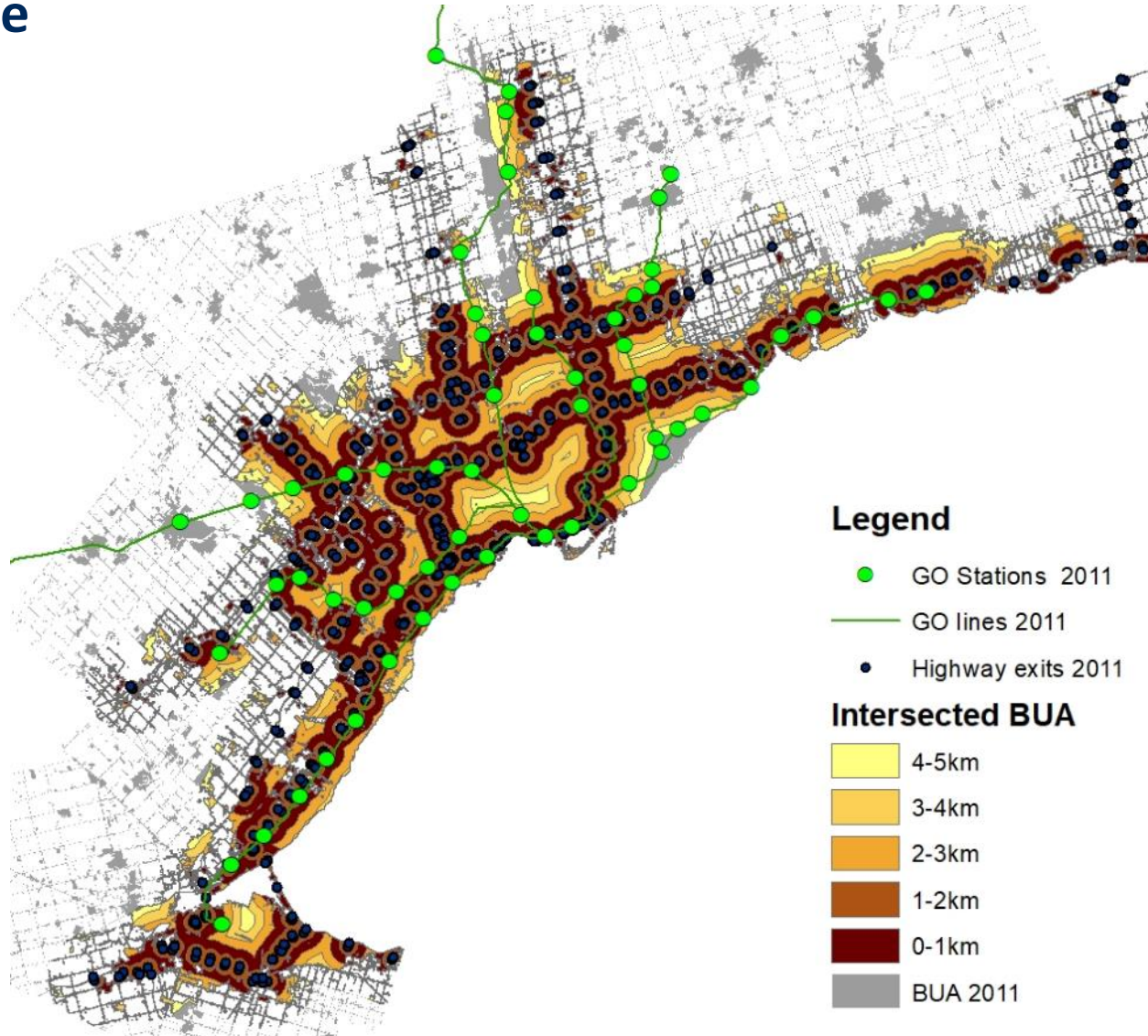
Key Findings

- The BUA around highway exits and rail stations follows a distance decay trend, i.e. inner 1 km buffers have more built up land than the outer buffers

- Urbanization - rail stations vs. highway exits:
  - On average 15% more built up land exists in the vicinity of highway exits compared to rail stations
  - Urban land around rail stations is more dense

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Preliminary analysis and findings: Travel behaviour study

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Total VKT and PKT generated

- VKT growth = 111%
- PKT growth = 130%
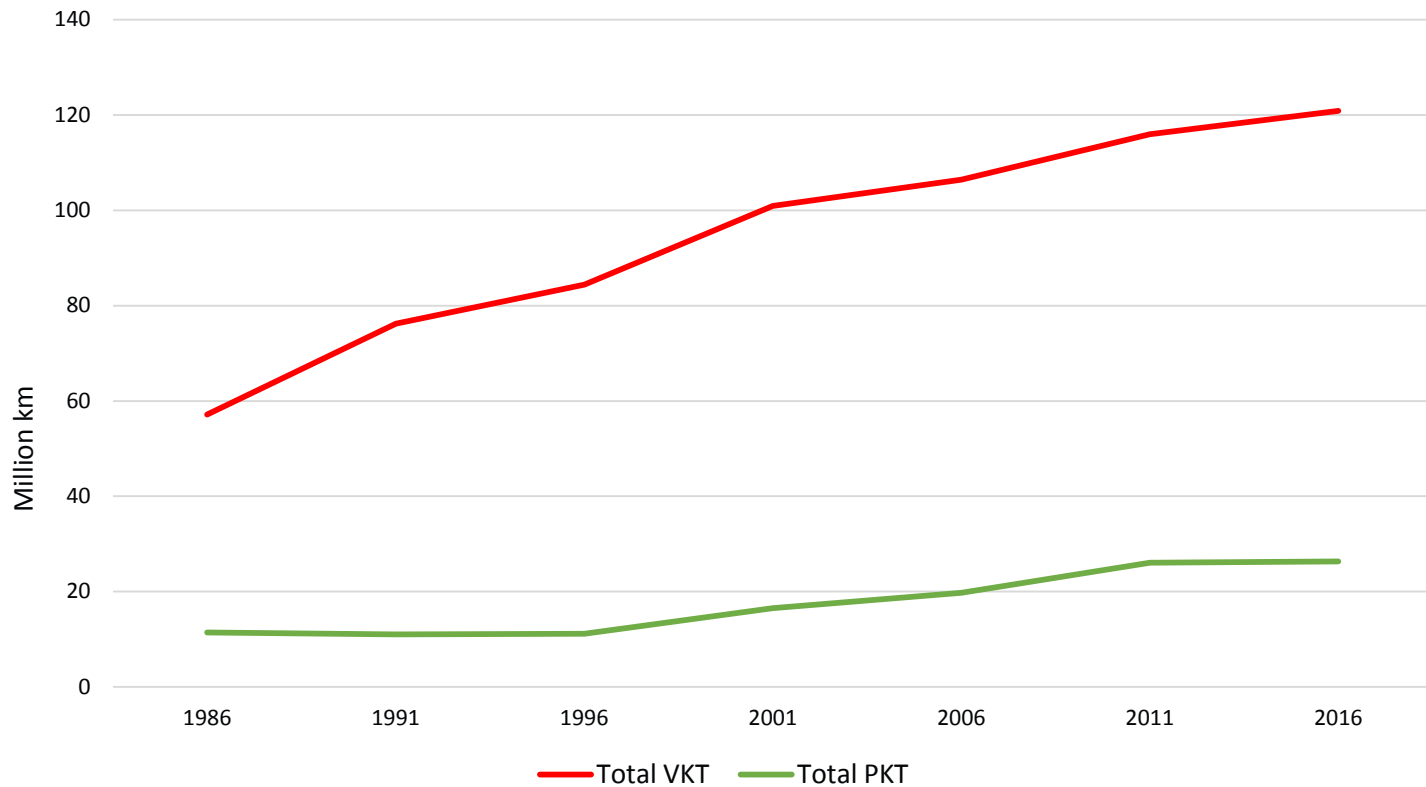
Total generated VKT by degree of urbanity

Highest VKT growth in the rural (but not very rural) areas
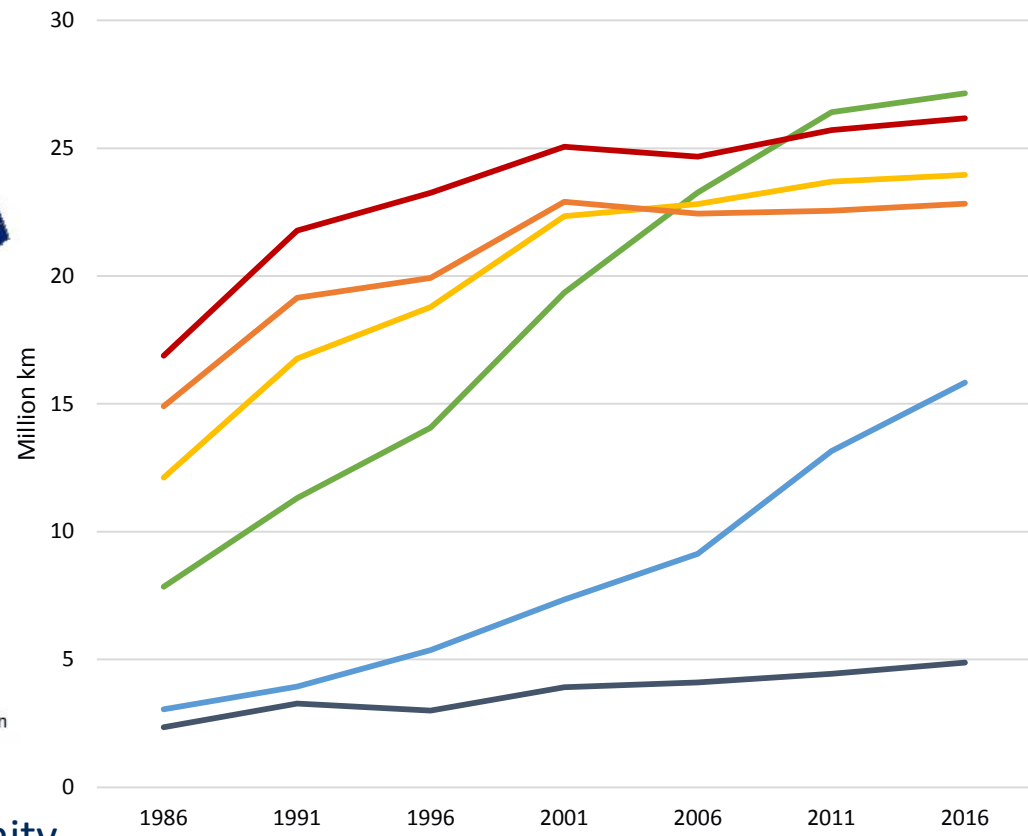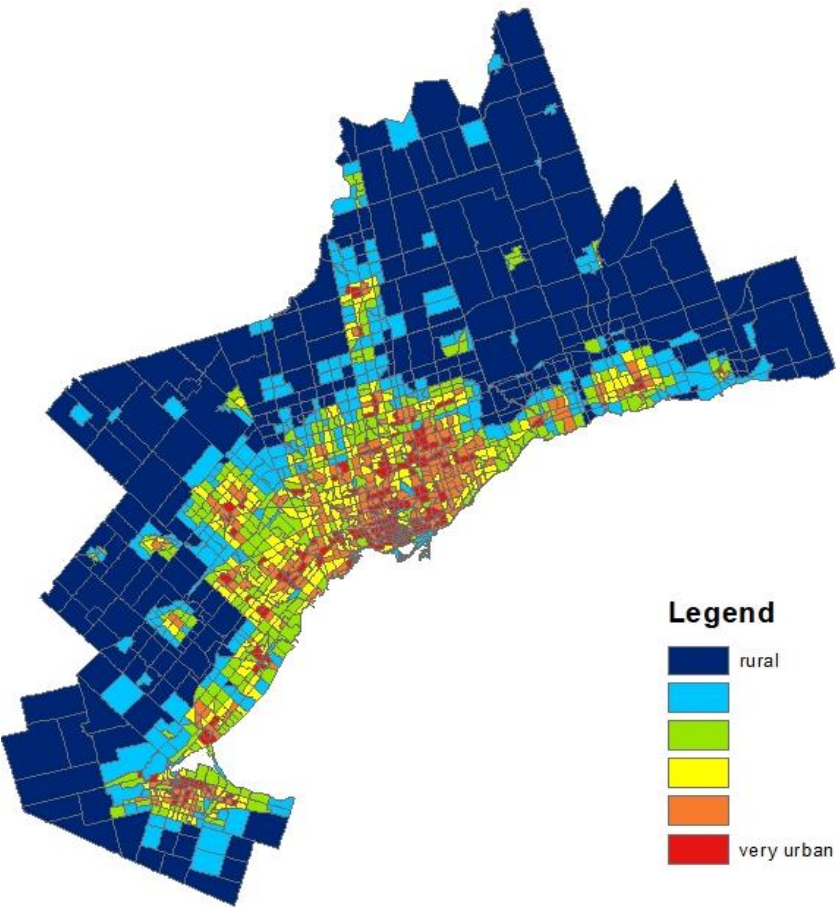
Trip density as a proxy for degree of urbanity

Total PKT generated by degree of urbanity

Highest PKT generation and growth in the very urban areas

Legend
- rural
- (light blue)
- (green)
- (yellow)
- (orange)
- very urban
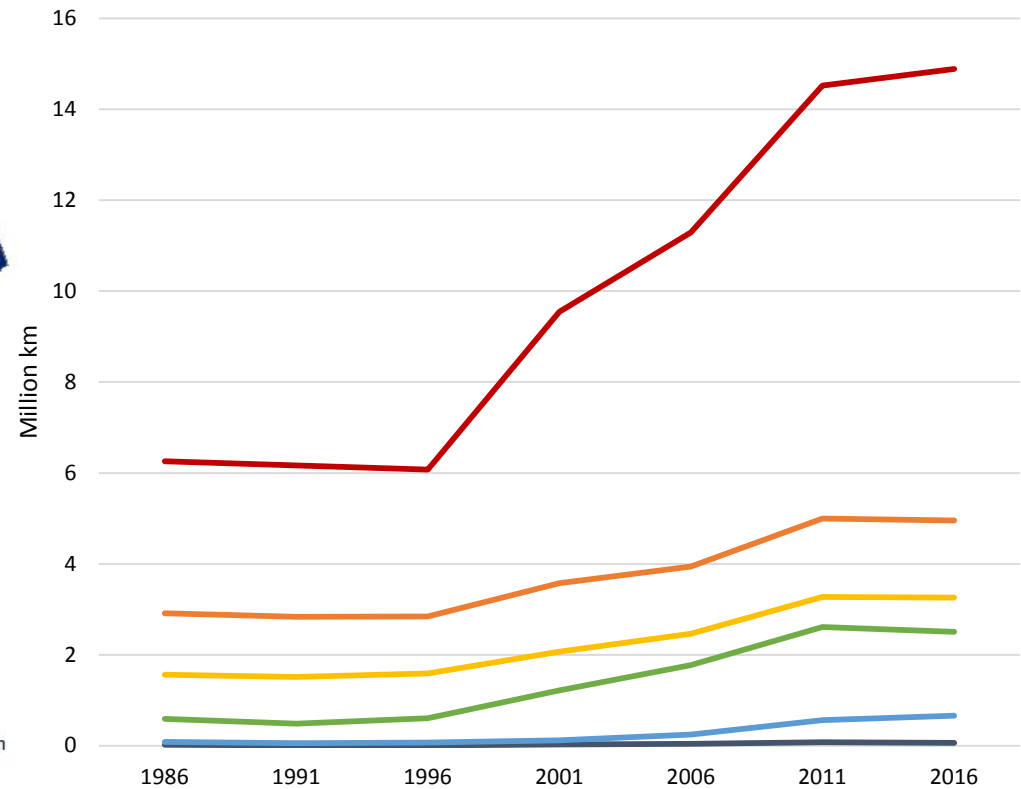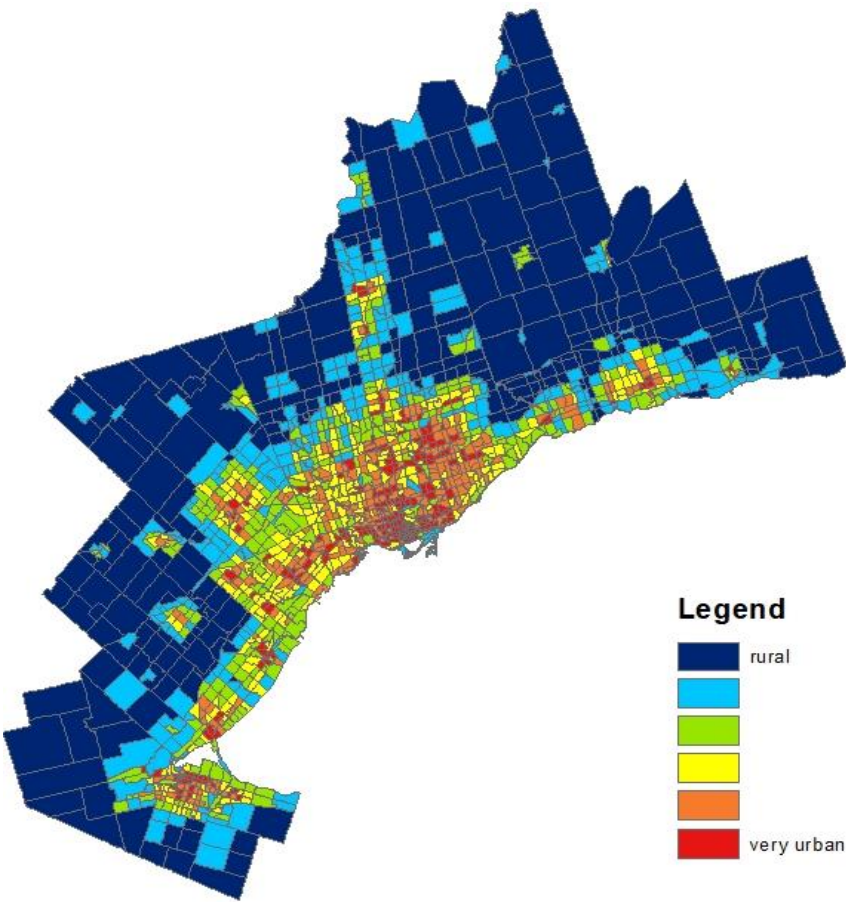
Mean VKT/trip and PKT/per trip

On average, GTHA residents are travelling longer distances by automobiles (1.5 km) and transit (4 km)
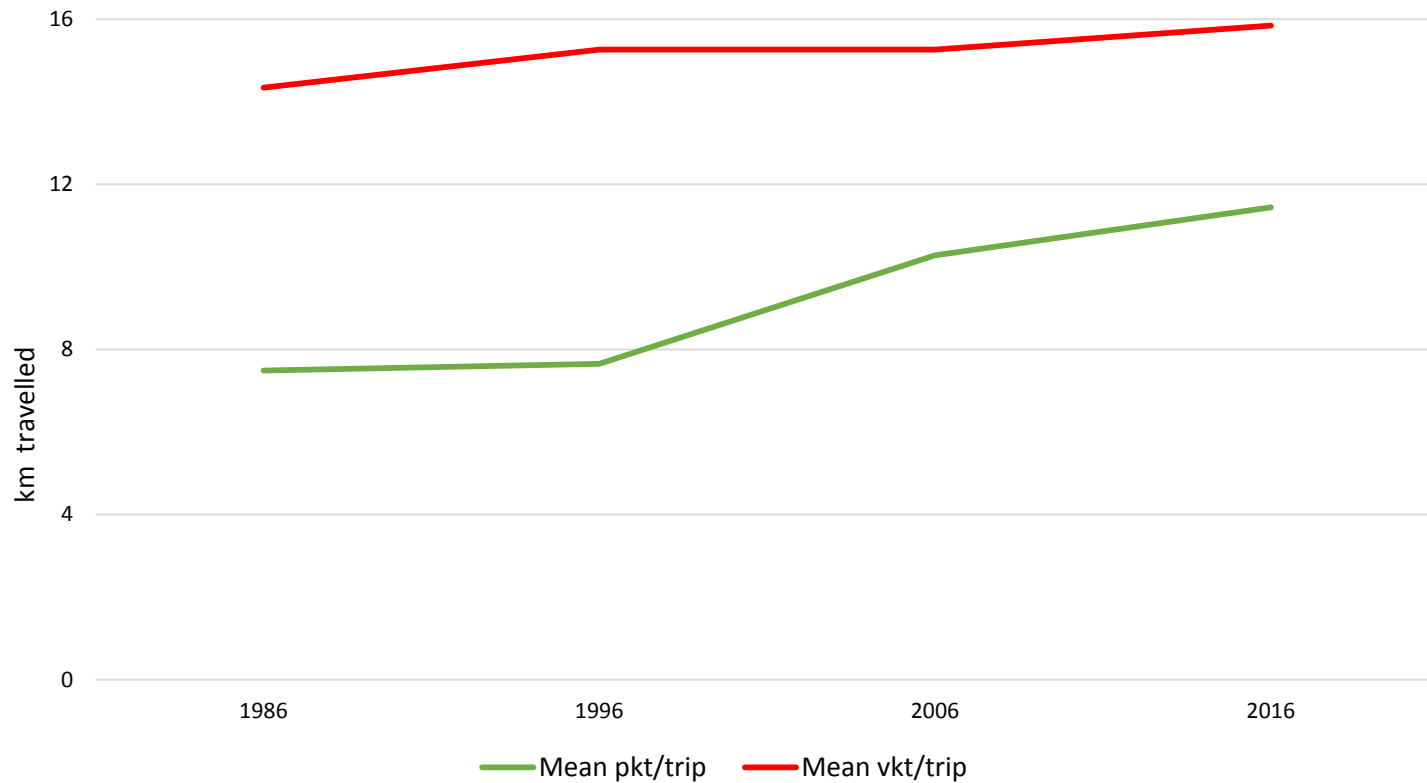
Pseudo-panel regression model results

Urban expansion:

Proximity to population centres vs. Transit accessibility

Centrality has 5 times larger impact on attracting urbanization than transit improvement
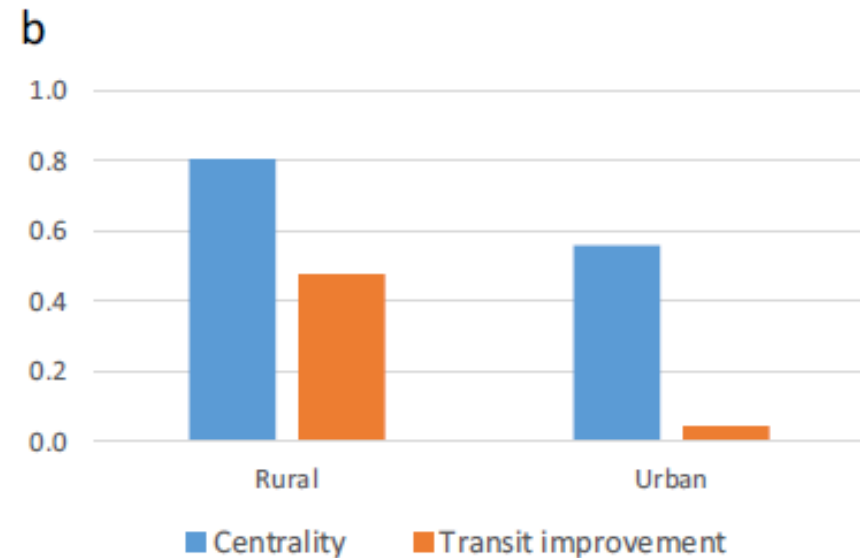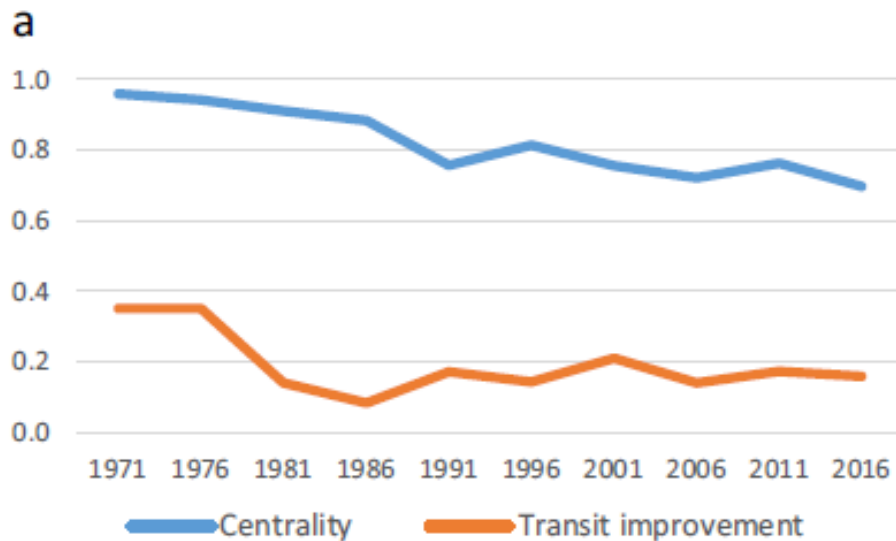
Diminishing influence of both indicators on urbanization over time and with increasing urbanity

Conclusions

Urbanization and transport accessibility

- Investment in transit infrastructure is not an effective growth management tool in saturated urban areas

- Intensify activity centers in TODs, rather than invest in reducing travel times to reach them

Travel behaviour model:

Travel demand = f(accessibility, socio-demographics, built form)

- The determinants of VKT and PKT in the GTHA:
  - Population density
  - Transit accessibility
  - Household income
  - Percent of households with no cars
  - Percent of seniors
- The effects vary significantly across space, but are fairly stable over time

Thank you!

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Appendix:
Data sources and availability

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Data sources and availability

Census variables	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Age categories (0-14, 15-29, 30-64, 65+)	√					√					√					√	√	√	√
Housing tenure (owned/rented)	√					√					√					√	√	√	√
Dwelling type (Single-detached, Apartment - 5 storeys or more, Single attached)	√					√					√					√	√	√	√
Average household size	√					√					√					√	√	√	√
Household size 1, 2, 3 and 3+	√					√					√					√	√	√	√
Marital status (single, married)	√					√					√					√	√	√	√
Couples with/without children	√					√					√					√	√	√	√
Immigrants and non-immigrants	√					√					√					√	√	√	√
Immigrants arrived in past 5 years	√					√					√					√	√	√	√
Visible minorities	√					√					√					√	√	√	√
Average # of rooms in a dwelling	√					√					√					√	√	√	√
Suitability of a dwelling (suitable/ unsuitable)	√					√					√					√	√	√	√
Total # of households	√					√					√					√	√	√	√
Age of structure (+46, 36-45, 26-35, 16-25, 6-15, 0-5)	√					√					√					√	√	√	√
Structural condition of dwelling (regular maintenance/ minor repairs and major repairs)	√					√					√					√	√	√	√
Mobility status (moved into the DA in the past 1 or 5 years)	√					√					√					√	√	√	√
Tenants or owners paying above 30% of income on shelter costs	√					√					√					√	√	√	√
Total employed labour force 15 years and over by mode of commuting (Car, truck, van as driver/ as passenger, Public transit, Walked, Bicycle, Motorcycle, Taxicab, Other)	√					√					√					√	√	√	√

Data sources and availability

Census variables	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Median/Average/categories HH income $	√					√					√					√	√	√	√
Average monthly shelter costs for rented dwellings ($)	√					√					√					√	√	√	√
Average monthly shelter costs for owned dwellings ($)	√					√					√					√	√	√	√
Average value of dwelling $	√					√					√					√	√	√	√
Total labour force 15 years and over	√					√					√					√	√	√	√
Employed laborforce	√					√					√					√	√	√	√
Unemployed laborforce	√					√					√					√	√	√	√
Not in the laborforce (or dependent population)	√					√					√					√	√	√	√
Participation rate	√					√					√					√	√	√	√
Employment rate	√					√					√					√	√	√	√
Unemployment rate	√					√					√					√	√	√	√
Classes of workers (Employee, Self-employed)	√					√					√					√	√	√	√
Employment industry classifications	√					√					√					√	√	√	√
Place of work status (Usual place of work (in CSD of residence/ in different CSD/ in same CD), At home, Outside Canada, No fixed workplace address))	√					√					√					√	√	√	√
Highest level of education (High school diploma/ certificate, Postsecondary certificate or diploma, Postsecondary degree)	√					√					√					√	√	√	√

Data sources and availability

TTS variables	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Number of persons and households	√					√					√					√	√	√	√
Number of full-time workers	√					√					√					√	√	√	√
Number of people working at home	√					√					√					√	√	√	√
Number of students	√					√					√					√	√	√	√
Zone of work (jobs)	√					√					√					√	√	√	
Number of vehicles owned by a household	√					√					√					√	√	√	√
Primary travel mode of transit trips (local transit without GO train, only GO train, both GO and local transit)	√					√					√					√	√	√	√
24-hr auto O-D trips	√					√					√					√	√	√	√

DMTI variables	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Land Use - CanMap RouteLogistics Ontario			√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Enhanced Points of Interest (EPOI) used to calculate neighborhood amenities (schools, clinics/hospitals, grocery stores, supermarkets, religious, eating places, childcares, public parks) in buffers of 400m and 800m around DA centroids	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√			

Detailed land use	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Dept. of Geography Land Use (GTA)				√	√	√													
Hamilton Open Data Land Use				√	√	√													

Teranet variables	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Housing sales price (median and average)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Housing sales count	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Number of years since last sale	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Average/median sales price	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Sales price to median price ratio	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

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Data sources and availability

Transportation accessibility	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Travel time by car and transit	√					√					√					√	√	√	√
Potential population access by car & transit	√					√					√					√	√	√	√
Relative potential population access by car and transit	√					√					√					√	√	√	√
Potential job access by car and transit	√					√					√					√	√	√	√
Relative potential job access by car and transit	√					√					√					√	√	√	√
Road and transit line densities	√					√					√					√	√	√	√
Distance to nearest rail station (straight-line and network)	√					√					√					√	√	√	√
Number of rail stations in 1km buffer radius	√					√					√					√	√	√	√

Built environment variables	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Distance of DA centroid to CBD	√																		
Location of DA centroid w.r.t. the Green Belt	√																		
Population and job densities	√					√					√					√	√	√	√

Macro-variables	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	1996	1991	1986
Percent of municipal population change (Census)	√					√					√					√			
Municipal unemployment rate (Census)	√					√					√					√			
Annual percent change in violent crime index - CD level (Statistics Canada)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Percent change in single housing starts - CD level (CMHC)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Annual prime rate (Bank of Canada)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			

UTTRI

Outlier treatment: Exclude observations > 3SD and > $10 million